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Research on the Influencing Factors of High-Quality Development of Urban Barrier-Free Environment Construction— Based on the DEMATEL-ISM-MICMAC Method

Tiantian Ma

School of Law, Humanities and Sociology, Wuhan University of Technology, Wuhan, Hubei, 430070, China

Abstract: As China enters a stage of deep population aging, developing inclusive urban barrier-free environments has become a key task for promoting social equity and high-quality development. Based on literature synthesis and expert consultation, this study employs the DEMATEL–ISM–MICMAC integrated approach to systematically identify and analyze the key factors influencing urban barrier-free construction. The framework encompasses four dimensions—policy support, infrastructure, socio-cultural environment, and management services—comprising sixteen factors. Results reveal that government planning, incentive mechanisms, and supervision systems form the core driving forces, while education and professional training play a pivotal role in bridging policy implementation and public awareness. Education serves not only as a channel of knowledge dissemination but also as a strategic lever for socializing accessibility concepts. The study suggests strengthening policy coordination and educational guidance, fostering technological innovation and institutional improvement, and optimizing service and infrastructure management to build a multi-level, sustainable governance system that ensures spatial inclusiveness and social participation.

Keywords: Barrier-free environment construction; High-quality development; DEMATEL-ISM-MICMAC method

1. Introduction

China faces deep population aging, with over 85 million people with disabilities and more than 260 million aged 60 and above, projected to exceed 300 million. Aging, chronic diseases, and injuries suggest rising disability rates. Ensuring that vulnerable groups—including older adults, persons with disabilities, children, and pregnant women—can fully participate in social and educational life is critical for social equity and educational inclusiveness[].Urban accessibility encompasses physical infrastructure, information systems, and social participation, providing mobility, convenience, and equitable access to resources. The 2023 Law on the Construction of Barrier-Free Environments institutionalizes accessible facilities, services, information, and educational opportunities. Despite policy progress, practical implementation remains uneven across cities[].Existing research has addressed legal frameworks, urban practice, and information accessibility but lacks systematic, empirical, and integrative analyses. To address these gaps, this study applies the DEMATEL–ISM–MICMAC framework to identify and analyze key factors across four dimensions: policy support, infrastructure, socio-cultural environment, and management systems, aiming to support high-quality development of accessible urban environments.

2. Research Methodology

This study integrates the Delphi method with the DEMATEL–ISM–MICMAC approach. The Delphi method, through multiple rounds of expert feedback, enhances the scientific rigor in factor selection and the construction of the influencing factor framework. DEMATEL quantifies the influence and the degree of being influenced among factors within a system, and calculates prominence and causality to classify factors[]. ISM clarifies the hierarchical structure of factors, visually representing their logical relationships. MICMAC identifies highly dependent and highly driving factors through a driving–dependence matrix, clarifying their systemic roles. The combined application of these three methods facilitates analysis of factor importance, hierarchical relationships, and system roles, standardizing the research process and improving the scientific validity of conclusions. This study is the first to apply this integrated methodology to urban barrier-free environment construction, aiming to develop a systematically structured and hierarchically clear framework of influencing factors.

2.1 Technical Roadmap of the Study

Step 1: Experts in the field were invited to screen, discuss, and draft the influencing factors of urban barrier-free environment construction, thereby constructing a comprehensive influencing factor system for urban barrier-free environment development.

Step 2: Using a questionnaire survey, experts were asked to evaluate the degree to which each factor in the influencing factor system affects other factors. The evaluation scale ranged from 0 to 4, representing no influence (0), low influence (1), medium influence (2), high influence (3), and very high influence (4).

Step 3: The initial direct-influence matrix W was constructed. After collecting the expert scoring data, the average value of each entry was calculated to establish the matrix $W=[w_{ij}]_{k\times k}$, where k represents the number of influencing factors, and w_{ij} denotes the degree of influence of factor i on factor j. The diagonal elements w_{ij} represent the influence of a factor on itself and are set to 0.

$$W=\begin{bmatrix} w_{11} & w_{12} & \cdots & w_{1(j-1)} & w_{1j} \\ w_{21} & w_{22} & \cdots & w_{2(j-1)} & w_{2j} \\ \cdots & \cdots & \ddots & \cdots & \cdots \\ w_{(i-1)1} & w_{(i-1)2} & \cdots & w_{(i-1)(j-1)} & w_{(i-1)j} \\ w_{i1} & w_{i2} & \cdots & w_{i(j-1)} & w_{ij} \end{bmatrix} \tag{1}$$

Step 4: The initial direct-influence matrix was normalized to obtain the normalized direct-influence matrix A.Here, k represents the total number of columns in the direct-influence matrix.

$$W_{max}=max\left\{\sum_{j=1}^{k} w_{ij}\right\} \tag{2}$$

$$a_{ij}=\frac{w_{ij}}{W_{max}}(i=1,2,\ldots,k) \tag{3}$$

$$A=\begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1(j-1)} & a_{1j} \\ a_{21} & a_{22} & \cdots & a_{2(j-1)} & a_{2j} \\ \cdots & \cdots & \ddots & \cdots & \cdots \\ a_{(i-1)1} & a_{(i-1)2} & \cdots & a_{(i-1)(j-1)} & a_{(i-1)j} \\ a_{i1} & a_{i2} & \cdots & a_{i(j-1)} & a_{ij} \end{bmatrix} \tag{4}$$

Step 5: The total influence matrix T was constructed. Here, I represents the identity matrix, and A denotes the normalized direct-influence matrix.

$$T=\lim_{n\to\infty}\left(A+A^2+A^3+\cdots+A^n\right)=A(I-A)^{-1} \tag{5}$$

Step 6: The influence degree, influenced degree, prominence, and relation of each factor were calculated. Here, D_i represents the degree to which factor i influences other factors, E_i represents the degree to which factor i is influenced by other factors, B_i denotes the prominence of factor i, and C_i denotes the relation of factor i.

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&

$$\text{influence degree:}D_i=\sum_{j=1}^{k} T_{ij}\left(i=1,2,\cdots,k\right) \tag{6}$$

$$\text{influenced degree:}E_i=\sum_{j=1}^{k} T_{ji}\left(i=1,2,\cdots,k\right) \tag{7}$$

$$\text{prominence}: B_i = D_i + E_i \quad (8)$$

$$\text{relation}: C_i = D_i - E_i \quad (9)$$

Step 7: The overall influence matrix *K* was constructed. Here, *T* represents the total influence matrix, and *I* denotes the identity matrix.

$$K = T + I \quad (10)$$

Step 8: The reachability matrix was calculated. A threshold λ was set such that if an element in the overall influence matrix *K* was greater than or equal to λ, the corresponding element in the reachability matrix S_{ij} was assigned a value of 1; otherwise, it was assigned a value of 0. Here, λ represents the threshold, and S_{ij} denotes an element of the reachability matrix.

$$S_{ij} = \{1 | k_{ij} \geq \lambda\}, (i=1,\ldots,n; j=1,\ldots,n) \quad (11)$$

$$S_{ij} = \{0 | k_{ij} < \lambda\}, (i=1,\ldots,n; j=1,\ldots,n) \quad (12)$$

Step 9: The reachability set, antecedent set, and intersection set were determined. For a specific element in the reachability matrix, all elements that it can influence form its reachability set. Conversely, all elements that influence a specific element form its antecedent set. The intersection of the reachability set and antecedent set forms the intersection set for that element. Here, $M(S_i)$ denotes the reachability set of the *i*-th element in the reachability matrix $N(S_i)$ denotes the antecedent set of the *i*-th element, and $R(S_i)$ represents the intersection set, which consists of the common elements in both the reachability and antecedent sets.

$$M(S_i) = \{s_i \in S | k_{ij} = 1\} \quad (13)$$

$$N(S_i) = \{s_i \in S | k_{ji} = 1\} \quad (14)$$

$$R(S_i) = M(S_i) \cap N(S_i), (i,j=1,2,\ldots,n) \quad (15)$$

Step 10: A multi-level hierarchical structure model was established. The hierarchical partitioning was conducted based on the principle $M(S_i) = R(S_i)$. First, the elements satisfying this condition were assigned to the first level. After identifying the first-level elements, their corresponding rows and columns in the reachability matrix were removed, and the process was repeated to determine the second level. This procedure was continued iteratively until all factors were assigned to their respective levels, resulting in a complete multi-level hierarchical structure model.

Step 11: The driving power and dependence of each factor were calculated. The driving power represents the degree to which a specific factor influences other factors, while the dependence indicates the extent to which a specific factor is influenced by other factors. Here, Q_i denotes the driving power of factor *i*, and Y_i denotes the dependence of factor *i*.

$$Q_i = \sum_{i=1}^{n} s_{ij} \quad (16)$$

$$Y_i = \sum_{j=1}^{n} s_{ij} \quad (17)$$

Step 12: The driving power–dependence matrix was constructed.

3. Construction of the Influencing Factor Model for Urban Barrier-Free Environment Development

The construction of urban barrier-free environments is influenced by a complex set of factors. Based on a systematic review and comprehensive analysis of relevant information, this study employed the Delphi method and invited experts from universities, research institutions, and related social organizations to form an expert panel. Through multiple rounds of surveys, repeated consultations, synthesis, and revisions, the study ultimately developed a model of the factors influencing urban barrier-free environment construction, as shown in Table 1.

Table 1. Description of Influencing Factors for High-Quality Development of Urban Barrier-Free Environment

	Dimension	Factor
High-Quality Development of Urban Barrier-Free Environment	Policy Environment and Support System	Laws and Regulations System x_1
		Government Planning and Strategy x_2
		Government Support and Incentive Mechanisms x_3
		Policies on Technological Innovation and Application Promotion x_4
	Infrastructure Construction and Renovation	Barrier-Free Public Transportation Facilities x_5
		Barrier-Free Public Building Spaces x_6
		Barrier-Free Community and Residential Facilities x_7
		x_8 Barrier-Free Information and Communication x_8
	Socio-Cultural Environment	Attention from Social Organizations x_9
		Media Publicity and Coverage Efforts x_{10}
		Popularization of Barrier-Free Knowledge in the Education System x_{11}
		Professional Talent Cultivation and Knowledge Updating Level x_{12}
	Management and Service System	Barrier-Free Service Level x_{13}
		Facility Management and Maintenance System x_{14}
		User Feedback Mechanism x_{15}
		Supervision and Evaluation Mechanism x_{16}

4. Research Process

4.1 Calculation of Prominence and Relation Based on DEMATEL

A total of ten experts were invited to participate in this study, including scholars in the fields of public administration and law, as well as managers from municipal-level Disabled Persons' Federations. The experts were asked to evaluate the interrelationships among the factors influencing urban barrier-free environment construction by completing structured questionnaires. To ensure the reliability of the survey results, the responses were subjected to reliability analysis using SPSS 27.0 software. The Cronbach's α coefficient exceeded 0.80, indicating a high level of internal consistency.

The average scores of the ten experts' evaluations were then used to construct the initial direct-influence matrix.

Based on Equations, the total influence matrix T was obtained, as shown in Table 2.

Table 2. Total Influence Matrix *T*

	x_1	x_2	x_3	x_4	x_5	x_6	x_7	x_8	x_9	x_{10}	x_{11}	x_{12}	x_{13}	x_{14}	x_{15}	x_{16}
x_1	0.15	0.15	0.15	0.20	0.14	0.13	0.24	0.21	0.21	0.18	0.19	0.22	0.11	0.16	0.19	0.18
x_2	0.25	0.15	0.20	0.24	0.16	0.16	0.27	0.24	0.24	0.23	0.24	0.26	0.16	0.19	0.23	0.23
x_3	0.29	0.20	0.17	0.28	0.18	0.17	0.31	0.29	0.29	0.27	0.28	0.30	0.17	0.19	0.25	0.24
x_4	0.23	0.17	0.18	0.16	0.17	0.15	0.26	0.23	0.22	0.21	0.22	0.25	0.13	0.17	0.21	0.21
x_5	0.19	0.15	0.14	0.16	0.10	0.12	0.23	0.17	0.17	0.17	0.16	0.20	0.11	0.16	0.20	0.20
x_6	0.16	0.14	0.13	0.15	0.14	0.09	0.21	0.16	0.16	0.17	0.15	0.19	0.11	0.14	0.17	0.18
x_7	0.17	0.17	0.16	0.17	0.14	0.13	0.16	0.18	0.17	0.17	0.17	0.20	0.11	0.13	0.16	0.16
x_8	0.22	0.16	0.16	0.21	0.14	0.14	0.25	0.16	0.22	0.18	0.20	0.24	0.13	0.18	0.22	0.20
x_9	0.20	0.14	0.15	0.19	0.12	0.12	0.22	0.20	0.14	0.17	0.18	0.22	0.12	0.14	0.19	0.18
x_{10}	0.15	0.15	0.15	0.15	0.12	0.12	0.19	0.15	0.15	0.12	0.17	0.20	0.11	0.14	0.16	0.16
x_{11}	0.23	0.19	0.20	0.22	0.17	0.16	0.28	0.23	0.23	0.22	0.16	0.26	0.15	0.17	0.21	0.22
x_{12}	0.20	0.17	0.18	0.19	0.13	0.13	0.25	0.20	0.20	0.18	0.19	0.16	0.12	0.15	0.18	0.18
x_{13}	0.19	0.17	0.17	0.19	0.14	0.14	0.23	0.19	0.19	0.18	0.19	0.22	0.10	0.19	0.22	0.22
x_{14}	0.16	0.14	0.15	0.15	0.15	0.14	0.19	0.19	0.16	0.15	0.15	0.17	0.13	0.11	0.19	0.17
x_{15}	0.20	0.17	0.17	0.19	0.15	0.14	0.22	0.20	0.19	0.17	0.19	0.23	0.13	0.19	0.15	0.20
x_{16}	0.24	0.20	0.21	0.23	0.17	0.16	0.27	0.24	0.23	0.21	0.23	0.27	0.14	0.21	0.25	0.17

Table 3. Influence Degree, Influenced Degree, Prominence, Relation, and Factor Type

Dimension	Factor	influence degree	influenced degree	prominence	Relation	Factor Type
Policy Environment and Support System	x_1 Legal and Regulatory Framework	2.80	3.22	6.02	-0.42	Effect Factors
	x_2 Government Planning and Strategy	3.44	2.60	6.05	0.84	Cause Factors
	x_3 Government Support and Incentive Mechanism	3.87	2.68	6.55	1.19	Cause Factors
	x_4 Policies for Technological Innovation and Application Promotion	3.18	3.08	6.26	0.10	Cause Factors
Infrastructure Construction and Renova-tion	x_5 Accessibility of Public Transportation Facilities	2.63	2.31	4.94	0.32	Cause Factors
	x_6 Accessibility of Public Buildings and Spaces	2.44	2.20	4.64	0.23	Cause Factors
	x_7 Accessibility of Communities and Residential Areas	2.55	3.77	6.33	-1.22	Effect Factors
	x_8 Accessibility of Information and Communication	3.03	3.26	6.29	-0.23	Effect Factors
Socio-Cultural Environment	x_9 Attention of Social Organizations	2.68	3.17	5.84	-0.49	Effect Factors
	x_{10} Intensity of Media Publicity and Reporting	2.38	2.98	5.37	-0.60	Effect Factors
	x_{11} Popularization of Accessibility Knowledge within the Education System	3.30	3.06	6.36	0.24	Cause Factors
	x_{12} Level of Professional Talent Training and Knowledge Renewal	2.83	3.59	6.41	-0.76	Effect Factors
Management and Service System	x_{13} Level of Accessibility Services	2.92	2.02	4.94	0.90	Cause Factors
	x_{14} Facility Management and Maintenance System	2.51	2.63	5.14	-0.13	Effect Factors
	x_{15} User Feedback Mechanism	2.89	3.19	6.08	-0.29	Effect Factors
	x_{16} Supervision and Evaluation Mechanism	3.41	3.10	6.51	0.31	Cause Factors

Specifically, linkage factors are characterized by high driving power and high dependence; dependent factors exhibit low driving power and high dependence; autonomous factors show low driving power and low dependence; and independent factors possess high driving power and low dependence.

5. Research Results and Policy Recommendations

5.1 Research Results

Based on the DEMATEL–ISM–MICMAC analysis, this study systematically identified the structure and mechanism of factors influencing urban barrier-free environment construction.

MICMAC results confirm this pattern: most key factors fall into the "driving" and "linkage" zones, indicating high systemic interdependence and sensitivity. Policy support acts as the principal driver, while infrastructure and service management play mediating roles, and cultural cognition represents the resultant layer. These findings highlight that accessibility construction is not a single-domain engineering task but a comprehensive governance process integrating policy formulation, technical realization, and cultural transformation.

In summary, the advancement of urban barrier-free environments depends on a multi-level interaction mechanism led by institutional innovation, supported by technological and managerial integration, and consolidated through cultural inclusivity. Strengthening coordination among these layers is essential for promoting the high-quality and sustainable development of accessible cities.

5.2 Policy Recommendations

To promote the high-quality development of urban barrier-free environments, the following policy recommendations are proposed:

(1) Strengthen institutional guarantees and policy coordination.

Governments at all levels should refine the legal and regulatory framework for accessibility, clarify departmental responsibilities, and ensure stable financial support. Establishing cross-sectoral coordination mechanisms can enhance the effectiveness of policy implementation and supervision.

(2) Prioritize education and awareness cultivation.

Education serves as the foundation for sustainable accessibility development. Integrating accessibility concepts into national education systems, professional training, and public campaigns can foster empathy, inclusiveness, and civic responsibility. Schools, universities, and community institutions should provide accessibility education and experiential programs to enhance public awareness, cultivate professional talent, and build a long-term cultural foundation for inclusive cities.

(3) Enhance technological innovation and smart governance.

Promoting digital accessibility through intelligent design, assistive technologies, and data platforms can improve urban management efficiency and service precision. Encouraging public–private collaboration and applying smart technologies in transportation, information, and public facilities can significantly elevate accessibility performance.

(4) Improve infrastructure and service systems.

Urban renewal projects should integrate barrier-free design into all stages of planning, construction, and management. Strengthening maintenance and supervision ensures that accessibility facilities remain functional and sustainable.

(5) Foster a collaborative social environment.

Building an inclusive social atmosphere requires joint participation from governments, enterprises, and citizens. Encouraging volunteerism, community participation, and media advocacy can form a co-governance pattern that supports equal participation and shared development for all.

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